REMARKS/ARGUMENTS

Applicant acknowledges, with thanks, the allowance of claims 3, 6, 8, 12, 15 and 17.

Claims 1, 2, 4, 5, 7, 9-11, 13, 14 and 16 stand rejected under 35 USC 103(a).

Independent claims 1, 9 and 10 and dependent claims 5, 7 and 14 are amended herein for greater clarity and/or to correct clerical errors.

The amendment to the description on page 14 simply links the term "basis signal" used in the claims with the term "subspace signal" used in the description.

No new subject matter has been added by these amendments.

FINAL Action

This office action was made FINAL but it is requested that the examiner rescind the finality of the office action, as necessary, and enter the amendments to the claims which merely clarify the claims to distinguish the claimed invention more clearly from the prior art and place the application in condition for allowance. The Request for Continued Examination submitted herewith would then be redundant in which case Applicant respectfully requests a refund.

General comments

The references relied upon by the examiner have been studied carefully and, for the reasons detailed below, it is submitted that **Li'024** and **Li'392** are not pertinent, any resemblance with the present invention, as claimed in at least independent claims 1, 9 and 10, being purely superficial. The other references relied upon by the examiner are specifically targeted at CDMA applications, as well as differing in other ways from the claimed invention. Contrary to the examiner's assertions, one cannot simply import features from those references into Li'024. As will be explained below, while the structures do seem similar superficially, upon closer inspection, it should be clear that the adaptation of the systems disclosed in these references to combine them with Li'024 is not trivial and would not necessarily result in a system in accordance with the present invention as claimed in claims 1, 9 and 10, and claims dependent thereupon.

The following is a brief summary of the differences between the present invention and each of the applied references.

Li'024: This patent is clearly directed at CDMA systems and exploits code knowledge in the

pre-processing section. In fact, two stages of interference nulling can be distinguished in the pre-processing section:

1- despreading through code correlation in code correlator 206 (cf. Fig. 2), a CDMA-specific operation, and

2- beamforming and nulling in the spatial combiners 212 (Fig. 2). The preprocessing section in the Applicant's specification is strictly used to reduce the space-time dimensions and performs no interference nulling or cancelling. In the interest of complexity reduction, interference nulling is left to the signal processing units downstream.

Li'392: This patent is concerned with clustered OFDM whereby each user occupies a different set of subcarriers. Therefore, multiple antenna reception is NOT required to separate users and can only serve to obtain diversity gain and thereby improve SNR. The eigenanalysis therein is performed on the frequency-correlation function as a means to compute channel estimates.

Huang: Also a clearly CDMA-specific patent which discloses a pre-processing section which performs despreading (and therefore interference rejection) and isolates resolvable paths, something only possible in CDMA. Therefore, in the general case, the number and nature of the basis functions differs from those of the Applicant's specification.

Hara: This third CDMA-specific patent describes a correlation matrix which, according to a modification described by Hara, can be submitted to eigendecomposition to find a transformation matrix that would lead to simpler processing. Hara's correlation matrix is that of the total received signal across <u>space only</u>, including contributions from all users. In the Applicant's specification, filters derive basis functions for individual user signals across <u>space and time</u> dimensions.

Rejection of claims 1, 9 and 10 under 35 U.S.C. 103(a)

In paragraph 4 of the Office Action, claims 1, 9 and 10 were rejected under 35 U.S.C. 103(a) as unpatentable over US 2004/0146024 (**Li'024**) in view of US 6,795,392 (**Li'392**). Applicant respectfully submits that claims 1, 9 and 10 are patentable over **Li' 024** and **Li '392** and has amended these claims to clarify the distinctions since it appears that they were not clear to the examiner.

With all due respect, the examiner has erred in reducing the inventive step to "... simply proving *(sic)* a large number of antennas with a smaller number of detected users (i.e., M

antennas > N users) *(sic)* and hence has erred in concluding that the "claimed limitation are *(sic)* made obvious by **Li '024** in view of **Li '392"**. That is an over-simplification. *(Note that there are actually M+1 users.)*

The present invention is directed to a *multi-user* system with multiple antennas but the number of antennas is not directly related to the number of users, providing there are more antennas than users. As shown in Applicant's Figure 1, the common preprocessing unit 40 has a separate dominant subspace filter for each user. Thus, there are **M+1** users so there are **M+1** dominant subspace filters (40/0 to 40/**M**). Likewise, there are **M+1** signal processors 60/1 to 60/**M**, one for each of the **M+1** users.

In the office action, while discussing Li'024, the examiner states on page 3 "...wherein one skilled in the art would recognize that the number of antennas can be more or less regardless of the number of users as disclosed in Li'392...". To support this assertion, the examiner cites Li'392, Col. 3 lines 20-24 where it is stated that "it should be understood that the arrangement could have *one antenna* or many antennas" [emphasis added]. With all due respect, contrary to the examiner's assertions, this statement in Li'392 actually teaches away from the present invention which must have at least as many antennas as users.

It is clear from Fig. 1 that Li'392 refers to a system where the different users are on different orthogonal carriers and therefore do not directly interfere with one another. This is clear also from Fig. 2, Li'392 which clearly shows the outputs of the antennas 11 and 21 routed to the same decision device 31. Therefore, these plural antennas are not used to separate the user signals in this context, but rather to improve the SNR through diversity gain. Likewise, in CDMA systems such as in Li'024, correlation with the unique user codes is used to separate the user signals, so that multiple antennas are not strictly necessary. Furthermore, CDMA channels are generally characterized by a very large bandwidth, such that the individual reflections in the channel impulse response are resolvable independently (this is usually done with a RAKE receiver structure), therefore considerably simplifying the equalization problem.

In contrast, embodiments of the present invention are systems in which multiple signals *on the same channel* are impinging on the antenna array and the multiple antenna elements are required to separate the signals. One skilled in this art would recognize that, in this case, the

multiple antenna elements *are* required to separate the user signals, and that there must be at least as many antennas as signals to achieve satisfactory performance. Thus, the selection of the number of antenna elements is based upon technical criteria and not simply a whim as implied by the examiner's assertion.

In addition, the equalization problem in wideband non-CDMA systems is difficult because the individual reflection paths in the impulse response are generally not resolvable. Therefore, continuous impulse responses with lengths of several symbol periods (maybe in the hundreds) must be "untangled" by linear equalizers (i.e., finite-impulse response filters with dynamically adaptive coefficients) or non-linear equalizers (decision-feedback, maximum-likelihood, etc.). In OFDM systems, the equalization problem is also much simpler because the channels on each subcarrier can be considered as narrowband. It is in fact recognized as being one of the main advantages of OFDM systems.

The present invention is advantageously applicable to (but not limited to) non-OFDM, non-CDMA wideband systems where multiple users co-exist on the same carrier. Multiple antennas are used (equal to or more than the number of co-channel signals) as well as multiple equalization taps (equal to or more than the length of the channel impulse response in symbol periods) on each antenna. Altogether, the number of taps which need to be adapted can be very large. For example, with 8 antennas and an impulse response length of 30 symbols, one would need to adapt 240 taps dynamically, which would lead to excessive complexity.

It should be appreciated that, in this example, one user's channel, as perceived over all 8 antennas and all 30 symbol delays, is referred to as a *space-time* channel. In embodiments of the present invention the dominant subspace filters 40 constitute a means, based on the subspace structure of the space-time channel, for intelligently reducing the number of dimensions that need to be processed using interference suppression processing (such as MMSE processing). It is based on eigenanalysis of the space-time channel to extract the dominant basis functions for each user. This is in complete contrast to the eigenanalysis and basis functions of **Li'392** which are derived from the frequency correlation function for channel estimation purposes. Dominant subspace filters aim to maximize the desired signal energy but perform no interference suppression, the latter function being relegated to later stages in the receiver.

In a multi-user context, one skilled in the art would recognize that maximizing the signal energy, or SNR, is not the same as maximizing the signal energy while nulling interference, i.e., maximizing the SINR (signal-to-interference-plus-noise ratio). The latter is maximized by minimizing the mean-square error, which is different from maximizing signal energy irrespective of interference. The two optimization criteria would only be equivalent if the interference were white noise only.

Embodiments of the present invention have **N** antenna elements (22/1 to 22/N) and **N** RF front end units (20/1 to 20/**N**) producing **N** antenna element signals (x_1 to x_N), where **N** is equal to at least the number of users **M+1**. <u>Every one of these **N** antenna element signals x_1 to x_N is supplied to every one of the **M+1** dominant subspace filters (40/0 to 40/**M**).</u> Hence, each of the **M+1** dominant subspace filters receives **N** antenna element signals and processes all **N** of them to produce a <u>single</u> subspace signal for the corresponding <u>single</u> user. Thus, the **M+1** dominant subspace filters 40/0 to 40/**M** produce **M+1** subspace signals y_0 to y_M. Every one of these subspace signals y_0 to y_M is supplied to every one of the user signal processors 60/1 to 60/**M**.

As explained at page 21, lines 6-16 of Applicant's original PCT specification, with reference to Figure 2, in the preferred embodiment each user-specific signal processor 60 comprises a plurality of multipliers $64/0_{00}$, ..., $64/0_M$ which apply weights w_{00}, ..., w_{0M} to subspace signals y_0, ..., y_M, respectively, from the dominant subspace filters 40/0, ..., 40/M. The weights w_{00}, ..., w_{0M} are derived in dependence upon substantially instantaneous channel characteristics, and updated. The weighted signals are then summed by combiner 62/0 whose output z_0 is fed to the detector 80/0 of Figure 1. Lines 15-16 of page 21 of Applicant's specification specifically state that *each of the other signal processors 40/1, ..., 40/M also uses all of the output signals* y_0, ..., y_M *to obtain its respective one of outputs* z_0, ..., z_M.

This is completely different from **Li '024**, <u>where no cross-coupling of antenna signal paths occurs before the spatial combiner blocks 212.</u> In Li'024 the user signals have been extracted using code correlation in code correlators 206. This is in complete contrast with the embodiments of the present invention which use dominant subspace filters 40.

Any similarity to the present applicant's system is superficial; when the structure and functionality of the preprocessing section are considered, it is apparent that they are not the same.

Claims 1, 9 and 10 have been amended, and clauses rearranged, to make the signal processing clearer and, in the process, make it clearer that the multi-user multiple antenna system and method of the present invention are neither disclosed in nor suggested by the cited references, whether taken individually or in combination. Simply put, there is no way to combine the systems disclosed in **Li'024** and **Li'392** and arrive at the present invention as claimed in claims 1, 9 and 10 even if a person of ordinary skill in this art were to try combining them.

It is well-established that, if the proposed modification or combination of the prior art would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render the claims *prima facie* obvious. (*In re* Ratti, 270 F.2d 810, 123 USPQ 349 (CCPA 1959)). Applicant respectfully submits that the asserted combination of **Li'024** and **Li'392** would not be *prima facie* obvious because **Li '024** relates to a CDMA-type system in which the interference suppression problem is both easier and very different since simply passing the signal through a filter matched to the code (or correlator) would ideally reduce all other signals to white noise. **Li'392** relates to an OFDM system which does not use code correlation at all. It is simply not enough to assert that a skilled person would try to combine Li'024 with Li'392 because Li'392 discloses plural antennas. Combining Li'024 with Li'392 would entail more than adding antennas; it would require corresponding changes to the processing of signals from those additional antennas, and the signal processing in Li'392 is not compatible with the signal processing in Li'024. Consequently, the skilled person would not be led to try combining them and, with respect, it is submitted that the examiner must have made the assertion based upon hindsight culled from the present Applicant's specification.

It should also be noted that, as illustrated in Fig. 1 of Applicant's application, Applicant's preprocessing section derives each of the basis function outputs as a function of all antennas. No direct relationship is observed in this respect with either **Li'392** or **Li'024**. Although **Li'392** makes use of an eigen-matrix approach and thus derives basis functions, they are used for channel estimation in frequency, a prerequisite to equalization in OFDM systems, which is unrelated to interference reduction. In Applicant's preprocessing section, the basis functions are derived over space and <u>time</u> (not frequency) and serve to separate multiple user signals (thus combatting mutual interference) with reasonable complexity.

It should also be noted that the present invention is not necessarily concerned with a

CDMA context, and the Applicant's signal processing units perform beamforming and nulling and produce "a respective one of a set of estimated received signals each for a corresponding one of the users." This is then routed to a classical detection device (80/0 through 80/M in Fig. 1 of Applicant's patent specification), <u>not to a joint detector as in Li'024</u>.

Yet another difference is that the basis functions which are input to Applicant's signal processing units 60/0 ... 60/M are not necessarily produced using foreknowledge of codes (such as code correlation, box 206 in Li'024), but can rely solely on knowledge of channels (delay profile, spatial signature, etc.) to maximize energy related to a specific user.

Also, each signal processing unit in the Applicant's specification takes all basis functions as inputs to perform the beamforming and nulling, instead of solely the signals related to one user (as in Li'024). In Li'024, the mention of maximizing energy in paragraph [0038] relates to the spatial signatures used in computing weights for the spatial combiners. This is not relevant to Applicant's maximizing of energy in the basis functions, which are produced by the preprocessing section.

With respect also to the dependent claims which stand rejected, another major difference as compared with Li'024 is that, in Applicant's specific embodiments, joint processing occurs both in the preprocessing section (of all antenna signals, with the goal of reducing the total number of dimensions for further processing, thus affording opportunities for reduced computational complexity), and in the signal processing sections.

It is clear, therefore, that the statement in the Office Action "Therefore, by simply providing a large number of antennas with a smaller number of detected users..." is irrelevant.

In view of these many differences, even in the unlikely event that a skilled person were to try combining the two references Li'024 and Li'392 (and it is not accepted that there would be any reason to try), the end result would not be the system of Applicant's claims 1, 9 and 10. It is submitted therefore that claims 1, 9 and 10 are patentable over the applied references.

Rejection of claims 1, 2, 4, 5, 7, 9-11, 13, 14 and 16 under 35 U.S.C. 103(a)

In paragraph 5 of the Office Action, claims 1, 2, 4, 5, 7, 9-11, 13, 14 and 16 were rejected under 35 U.S.C. 103(a) as unpatentable over US 6,301,293 (Huang) in view of US 6,934,323 (Hara) and US 6,795,392 (Li'392). This rejection is respectfully traversed.

It should be observed first and foremost that both Huang and Hara are clearly CDMA-

specific disclosures. In the second line of claim 1 of Huang, we have "...multiple direct-sequence spread-spectrum signals from K users...," thus clearly specializing the patent to this specific form of CDMA.

Again, the preprocessing section in Huang (box 16 in Fig. 2) assumes some foreknowledge of codes, using such codes to extract each resolvable path in a standard RAKE receiver structure. While this preprocessing section might produce signals which "maximize energy" for each user, it does so by relying on foreknowledge of codes, and the very wide bandwidth of CDMA signals (which makes for resolvable paths) enables a nice reduction in the number of dimensions, i.e., no equalization is required beyond the preprocessing section. This is not possible in the general case.

The foreknowledge of codes and the fact that paths are individually resolvable enables the RAKE (or matched filter) receivers to extract one or more dominant paths out of the impulse response of each user. Most of the interference is then reduced to white noise. In effect, after matched filtering, it is equivalent to having the users on different channels with very little crosstalk.

In Applicant's amended claims 1, 9 and 10, it has been clarified that the basis functions ($\mathbf{y}_0$, ... $\mathbf{y}_M$) are actually vectors with R elements, as indicated by the bold type notation. This is supported by the specification and the figures. This indicates that there might be more than one output signal from the preprocessing section associated with any one user. The number of such signals is determined according to the severity (i.e. memory length) of the channel, as well as the desired cost/complexity trade-off.

Although Applicant's basis functions are akin to matched filtering, the filters would be matched to the user's space-time channel in order to maximize energy, not to the user's code as is the case in Huang, Li'024, and Hara.

Hara discloses a two-step structure which might at first glance seem similar to that disclosed in Applicant's specification and claimed in claims 1, 2 and 10. As mentioned above, however, in "real world" CDMA applications it has been found that the orthogonality between codes could not be maintained, and thus, that some correlation could be observed at the receiver which was often detrimental to performance. Hara's solution is to "decorrelate" the signatures in the preprocessing step. This is very different from the present invention. Again, no foreknowledge of codes or CDMA context is assumed. Furthermore, the preprocessing section

seeks to produce signals which "maximize" energy for each user, irrespective of any other signals/interference which might be present. In other words, no joint processing (in terms of user signals) occurs in the preprocessing section.

Furthermore, the Office Action states on page 6:

> " ... wherein it is clear that the MMSE criterion would obviously exhibit a desired optimized concentration of energy of that desired user's received signal."

With all due respect, this is not so. The MMSE criterion maximizes the signal-to-(interference-plus-noise) ratio; not the signal energy itself. The confusion might arise because, in CDMA, most of the interference behaves as white noise, in which case the two criteria are nearly equivalent. This is far from true in the general case where strong structured interference is present.

The goal is to produce a number of basis functions for further processing. The preprocessing does not therefore tackle interference in any way, but leaves that job to the subsequent signal processing sections. The use of the MMSE criterion necessarily implies a direct attack on interference.

Regarding claim 2, the Office Action further asserts that the adjustment of parameters in dependence upon channel characteristics is obvious based on Huang and Hara. Again, it should be noted that the channel parameters updated in Huang are the resolvable path gains, in a purely CDMA-specific context. The Office Action then states " ... that would obviously be updated in the similar way as of the updating of eigenvector in Hara, see col. 11, lines 1-5, which clearly suggest that the eigenvector/weight is updated for every sampling period in dependence upon channel characteristics of all user channels with the correlation matrix\phi".

In fact, col. 11, lines 1-5 merely states that the matrix multiplication (by conversion matrix Λ defined in eq. (20) and mentioned in claim 6) leading to decorrelation is performed in every symbol period. The updating of the eigenvectors which make up matrix Λ could not possibly be performed that fast and would serve no purpose since the channels do not vary that rapidly in practical applications. In fact, the conversion matrix is obtained through eigendecomposition, a lengthy and complex process, and no mention of efficient updating means of the conversion matrix thus obtained (akin to the Applicant's basis functions in a certain way) is made in Hara.

Also, this eigendecomposition is performed on a spatial correlation matrix (with no time

dimension) that is the *sum of all user signals*. In embodiments of the present invention eigendecomposition is performed on *each user's space-time signal* independently, and efficient updating means are described in the specification.

Regarding claim 4: The claim is dependent upon claim 1 and so patentable with it. Moreover, the Office Action states:

> "Huang teaches that the number of basis signals is equal to the number of desired user signals."

This is not quite correct, and not in line with the Applicant's specification and claims which state that the total number of basis signals is equal to the number of desired user signals $M+1$ times a quantity R which can be one or more, depending on the length of the channel impulse responses and the desired performance level. Furthermore, the basis functions in Huang are different, since they are obtained by correlation with the user's code and thus imply interference suppression at that stage through the act of despreading, something that is not possible in the general case.

The Office Action also states (on page 7):

> "Regarding claim 5, the claim is rejected for the same reason as set forth in claim 1 above. In addition, it is clear the common preprocessing section [...] would comprise (k users) dominant subspace filters and would producing *(sic)* a set of basis signals that would obviously project the input signal of nth user carrying the most energy to the output of the nth basic signal as claimed (i.e., obtained via matched filter and weighted coefficients as an obvious desired result for any filter design intended for a multi-user detection)."

Again, this presumes a matched filter or correlator in the CDMA sense. There is no matched filter or correlator anywhere in the Applicant's preprocessing section, since Applicant assumes neither foreknowledge of user codes nor a CDMA context. Also, the difficulty of the problem is different in a non-CDMA context. The multi-user structure of Huang, for example, can rely on the codes as a first processing step (matched filter bank) thus considerably reducing interference, and also on the resolvable paths afforded by the large bandwidth of CDMA signals to avoid any form of explicit equalization. In general, a non-CDMA array receiver would also have to perform equalization and the number of taps to adapt would be proportional to both the number of antennas and the memory length of the channel (and thus could be considered excessive, in terms of computational complexity). Thus, the preprocessing section aims to reduce this excessive number of dimensions by producing a certain number of basis functions, based on channel

knowledge alone, (as specified by claim 2), and not on any user codes (although user codes could be exploited to gain such channel knowledge).

Hence, if the preprocessing section is to be viewed as a form of matched filter, it is matched to the space-time channels themselves, not to the user signatures or codes, and in that sense is completely different from matched filters as used in CDMA receivers as a preprocessing step in multi-user reception.

It is submitted, therefore, that claims 1, 2, 4, 5, 7, 9-11, 13, 14 and 16 are patentable over Li'024, Li'392, Huang and Hara, whether taken individually or in combination.

Accordingly, it is submitted that all claims of record are patentable and early and favourable reconsideration of the application is respectfully requested.

Respectfully submitted

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